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Blockchain technologies empowering peer-to-peer trading in multi-energy systems

Hua, Weiqi; Luo, Fengji; Du, Liang; Chen, Sijie; Kim, Taesic; Morstyn, Thomas; Robu, Valentin; Zhou, Yue

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GUEST EDITORIAL

Blockchain technologies empowering peer-to-peer trading in multi-energy systems: From advanced technologies towards applications

In efforts to decarbonise electricity, transport, and heating sectors, policy makers facilitate the integration of renewable energy sources and demand side management in multi-energy systems. With the support of the smart grid, an increasing number of consumers start to produce, store, and consume energy using zero-carbon electricity and heating sources, for example, solar panels, electric vehicles, and air source heat pumps, giving them the new role of multi-energy prosumers. A flexible local energy market structure and intelligent operations of smart grid are crucial factors for accommodating the role of multi-energy prosumers. The blockchain technologies, for example, smart contracts and hypothetical technology, pave the path for the peer-to-peer (P2P) energy markets, which are open and accessible to prosumers with enhanced automation, security, and privacy. The state-of-the-art research and scientific innovations bring these advanced blockchain technologies towards applications into multi-energy systems.

This special issue aims to solicit the innovative research on the blockchain empowering peer-to-peer trading in multi-energy systems. The scope of the research includes a single (multiple) energy vector(s) (e.g., electricity, gas, or heat), technologies (e.g., blockchain, smart contracts, or machine learning), theories (e.g., P2P trading mechanisms, pricing schemes, communication protocols, or consensus mechanisms) and applications (e.g., blockchain platforms or prosumer-centric energy scheduling).

There are in total six papers accepted for publication in this Special Issue after the careful peer-review and revision process. The selected papers are broadly categorised into three topics, with details provided as follows:

1 | TOPIC A: DESIGN OF BLOCKCHAIN PLATFORMS AND PROTOCOLS FOR PEER-TO-PEER ENERGY TRADING

'Research on Key Technologies of P2P Transaction in Virtual Power Plant Based on Blockchain' proposed by Li *et al.* analysed the consensus mechanism and smart contract of the blockchain technology in order to support the transaction interaction between internal resources of virtual power plants. The interactions of multiple energy sources within the virtual power plants, including the solar photovoltaic, hydro power, wind power, storage equipment, and electric car, were modelled by the game theory. These energy sources optimally complement each other in a manner of the P2P energy trading under the designed blockchain networks.

'Evaluating the Added Value of Blockchains to Local Energy Markets–Comparing the Performance of Blockchain-Based and Centralized Implementations' proposed by Zade *et al.* investigated the potential applications of blockchain technologies on the local energy markets. A comparative performance analysis between a blockchain-based and a central local energy market was performed to highlight the requirement of local energy markets for blockchain technologies. A periodic double auction and settlement mechanism was designed to support the operation of blockchain-based local energy markets. The simulation results demonstrated that the computational efficiency and security of current blockchain technologies were unable to fulfil the requirements of local energy markets.

'Dual-Blockchain Based P2P Energy Trading System with an Improved Optimistic Rollup Mechanism' proposed by Yu *et al.* designed a dual-blockchain system for P2P energy trading to address the scalability issue caused by the long computational time of current blockchain technologies. The system consists of a primary blockchain and a secondary blockchain, in which the primary blockchain is responsible for storing transactions of P2P energy trading while the compute-intensive tasks are executed in the secondary blockchain. An Improved Optimistic Rollup mechanism was also proposed to facilitate the co-operation of the dual blockchains for improving the computational efficiency and ensuring the correctness and security of transactions. A prototype implemented on Fisco Bcos and Alibaba Cloud was developed to validate the proposed system.

2 | TOPIC B: ARTIFICIAL INTELLIGENCE IN SUPPORTING PROSUMER-CENTRIC LOCAL ENERGY SYSTEM

'A Multi-Objective Multi-Agent Deep Reinforcement Learning Approach to Residential Appliance Scheduling' proposed by Lu *et al.* designed a multi-objective reinforcement learning algorithm for the demand side management of residential prosumers. The multiple preferences of appliances were optimally scheduled by the deep Q-network, including the electricity cost, peak demand, and punctuality. The proposed model could reduce the cost and peak power while improving the punctuality, compared to the rule-based approach for appliance scheduling. This research provides a potential solution to optimally control increasing numbers of residential prosumers and targets on individual prosumers' preferences.

3 | TOPIC C: MANAGEMENT OF DISTRIBUTION NETWORKS WITH THE UPTAKE OF PEER-TO-PEER ENERGY TRADING

'Design Choices in Peer-to-Peer Energy Markets with Active Network Management: A Comparative Analysis of Allocation Methods in Representative German Municipalities' proposed by Regener *et al.* assessed the management of distribution networks and design of P2P energy markets in terms of the user acceptance, economic performance, practicability, and their ability to relieve the grid congestion. The competing allocation mechanisms were analysed under network constraints using multiple key performance indicators, including the communal revenues or welfare distribution. An agent-based simulation framework built on data from three German reference municipalities was performed. With the growing number of distributed energy resources and new electrical loads at the sectoral contact points, the research highlights current implementation obstacles and promising concepts on P2P energy trading.

'Prosumer-Centric Energy Storage System and High Voltage Distribution Network Topology Co-Optimization for Urban Grid Congestion Management' proposed by Zhang *et al.* co-optimised the energy storage systems and high voltage distribution networks to overcome the challenges brought by the involvement of prosumers and distributed renewable energy sources. A bi-level optimisation model was designed, through which the AC optimal power flow was solved in the upper level to reduce the network congestion and a mixed-integer second order cone programming model was built in the lower level for the high voltage distribution network reconfiguration. The proposed model is able to reduce the frequency of network reconfiguration while maintaining the transmission congestion.

Weiqi Hua[1]
Fengji Luo[2]
Liang Du[3]
Sijie Chen[4]
Taesic Kim[5]
Thomas Morstyn[6]
Valentin Robu[7]
Yue Zhou[8]

[1]Department of Engineering Science, University of Oxford, Oxford, UK
[2]School of Civil Engineering, University of Sydney, Sydney, New South Wales, Australia
[3]Department of Electrical and Computer Engineering, Temple University, Philadelphia, Pennsylvania, USA
[4]Department of Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China
[5]Department of Electrical Engineering and Computer Science, Texas A&M University Kingsvillem, Kingsville, Texas, USA
[6]School of Engineering, University of Edinburgh, Edinburgh, UK
[7]Centrum Wiskunde & Informatica (CWI), Amsterdam, The Netherlands
[8]School of Engineering, Cardiff University, Cardiff, UK

Correspondence

Weiqi Hua, Department of Engineering Science, University of Oxford, Oxford, UK.
Email: weiqi.hua@eng.ox.ac.uk

Yue Zhou, School of Engineering, Cardiff University, Cardiff, UK.
Email: zhouy68@cardiff.ac.uk

ORCID

Weiqi Hua https://orcid.org/0000-0002-6616-6797
Fengji Luo https://orcid.org/0000-0002-7460-198X
Sijie Chen https://orcid.org/0000-0001-6553-7915

AUTHOR BIOGRAPHIES

Dr Weiqi Hua, University of Oxford, UK: Dr Weiqi Hua received his MSc and Ph.D. degrees in Engineering from the University of Durham, UK, in 2017 and 2020, respectively, and then took the postdoctoral position with Cardiff University in 2020. Since 2021, he has been with the University of Oxford, UK, as a postdoc researcher. His research interests include energy system modelling, energy system digitalisation, and peer-to-peer energy trading. He served as a Guest Editor for IET Smart Grid on the topic of peer-to-peer energy trading and for Water on the topic of energy-water nexus.

Dr Fengji Luo, University of Sydney, Australia: Dr Fengji Luo received his bachelor and master degrees in Software Engineering from Chongqing University, China, in 2006 and 2009. He received his Ph.D degree in Electrical Engineering from The University of Newcastle, Australia, 2014. Currently, he is a Lecturer and Academic Fellow in the School of Civil Engineering, The University of Sydney, Australia. He held positions in the Centre for Intelligent Electricity Networks, The University of Newcastle, Australian and Hong Kong Polytechnic University. He held a UUKI Rutherford International Researcher position in the Future Energy Institute, Brunel University London in 2018. His research interests include energy demand side management, smart grid, active distribution networks, and energy informatics. He has over 160 technical publications in these fields; his publications have been cited over 6700 times with the h-index of 43 (Google Scholar). He received the Pro-Vice Chancellor's Research and Innovation Excellence Award of The University of Newcastle in 2015 and ATSE's Australia-Japan Emerging Research Leader Programme in 2016. In 2020, he was named as Australia's Field Leader of Power Engineering by The Australian.
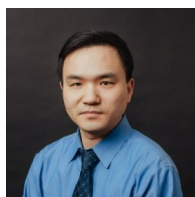
Dr Liang Du, Temple University, USA: Dr Liang Du received his Ph.D degree in electrical engineering from the Georgia Institute of Technology, Atlanta, GA in 2013. He was a Research Intern at Eaton Corp. Innovation Centre (Milwaukee, WI), Mitsubishi Electric Research Labs (Cambridge, MA), and Philips Research N.A. (Briarcliff Manor, NY) in 2011, 2012, and 2013, respectively. He was an Electrical Engineer with Schlumberger, Sugar Land, TX, from 2013 to 2017. He is currently an Assistant Professor with the Department of Electrical and Computer Engineering at Temple University, Philadelphia. Dr. Du received the Ralph E. Powe Junior Faculty Enhancement Award from ORAU in 2018 and two best paper awards from the IEEE Power and Energy Society General Meeting in 2021 and 2022. He currently serves as an associate editor of IEEE Transactions on Industry Applications and IEEE Transactions on Transportation Electrification.

Dr Sijie Chen, Shanghai Jiao Tong University, China: Dr. Sijie Chen is currently an Associate Professor in the Department of Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China. He received his B.E. and Ph.D. degrees in electrical engineering from Tsinghua University, Beijing, China, in 2009 and 2014, respectively. His research interests include energy block-chain, electricity market, demand response, and transactive energy system. He is a recipient of the 2017 Young Elite Scientists Sponsorship Programme by the China Association for Science and Technology, a recipient of the 2017 Shanghai Pujiang Talent Award, a recipient of Youth Expert by Shanghai Jiao Tong University, and a recipient of China Power Technology Innovation Second Prize. He was the chair of the IEEE PES SBLC blockchain working group and a co-chair of the IEEE PES SBLC load aggregator and distribution market working group.
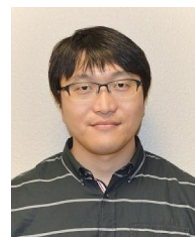
Dr Taesic Kim, Texas A&M University–Kingsville, USA: Dr. Taesic Kim received her M.S. and Ph.D. degrees in Electrical Engineering and Computer Engineering from the University of Nebraska—Lincoln, USA, in 2012 and 2105, respectively. In 2009, he was with the New and Renewable Energy Research Group of Korea Electrotechnology Research Institute (KERI), South Korea. He was also with Mitsubishi Electric Research Laboratories, Cambridge, MA, USA, in 2013. Currently, he is an associate professor in the Department of Electrical Engineering and Computer Science at the Texas A&M University-Kingsville (TAMUK). He directs the Cyber-Physical Power and Energy Systems (CPPES) group and focuses on research in cybersecurity, blockchain, resilient cyber-physical system, power electronics, and AI for power and energy systems sponsored by U.S. DOE, NSF, KERI, IITP, IEEE Foundation, and Microsoft. He holds 2 U.S. patents and more than 80 papers in refereed journals and IEEE conference proceedings in the field of CPPES. He is a recipient of the Dean's Award in Excellence in Research as well as Professor of Year in 2021 from TAMUK, IEEE Myron Zucker Student-Faculty Grant Award in 2018, two Best Paper Awards in the 2021 IEEE PES ISGT-ASIA and the 2017 IEEE International Conference on Electro Information Technology, and the First Prize Award in the 2013 IEEE IAS Graduate Student Thesis Contest.

Dr Thomas Morstyn, University of Edinburgh, UK: Dr Thomas Morstyn received his BEng (Hon.) degree from the University of Melbourne in 2011 and his PhD degree from the University of New South Wales in 2016, both in electrical engineering. He is Lecturer of Power Electronics and Smart Grids with the School of Engineering at the University of Edinburgh. He is also Deputy Champion of Energy Distribution and Infrastructure for the Scottish Energy Technology Partnership (ETP) and an Associate Editor of IEEE Transactions on Power Systems. His research interests include multi-agent control and market design for the large-scale integration of distributed energy resources into power systems.

Dr Valentin Robu, CWI, Amsterdam & TU Delft, Netherlands: Dr Valentin Robu received his Master of Science degree from VU Amsterdam, in 2003, with a specialisation in artificial intelligence, and his Ph.D. degree from the TU Eindhoven and CWI, Amsterdam, in 2009. Before October 2020, he was an associate professor at Heriot-Watt University, Edinburgh, UK. He is currently a senior staff researcher at CWI, National Research Institute for Mathematics and Computer Science, Amsterdam, and a part-time associate professor, TU Delft, The Netherlands. He is also a research affiliate at the Center for Collective Intelligence at MIT in the US. He has published over 180 papers in top-ranked journals and conferences, both in the areas of AI, energy and electrical engineering. He served as PI and Co-I in several large energy and AI-focussed research projects, including the UK National Centre for Energy Systems Integration, Offshore Robotics hub for Certification of Assets (ORCA Hub), and Responsive Flexibility (ReFlex), the UK's largest smart energy demonstrator. His work was distinguished by a number of prizes, including the IET 1029 Innovation of the Year Award, for his work with Scottish Power Energy Networks.
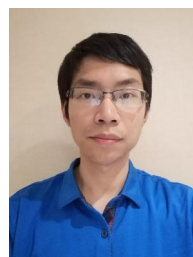
Dr Yue Zhou, Cardiff University, UK: Dr Yue Zhou received his BSc, MSc and Ph.D. degrees in Electrical Engineering from Tianjin University, China, in 2011, 2016 and 2016, respectively. He is the Lecturer in Cyber Physical Systems at the School of Engineering of Cardiff University, Wales, UK. His research interests include demand response, peer-to-peer energy trading and cyber physical systems. He is a Managing Editor of Applied Energy and an Associate Editor of IET Energy Systems Integration, IET Renewable Power Generation, Frontiers in Energy Research and CSEE Journal of Power and Energy Systems. He is the Chair of CIGRE UK Next Generation Network (NGN) Committee. He is also a Committee Member of IEEE PES UK & Ireland Chapter.